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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Don Wesley	ARNOLD	Livermore, California

Additional inventors are being named on the ________ separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max)

Improved Optical Detection Device

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 8 ☐ CD(s), Number ________

☑ Drawing(s) *Number of Sheets* 5 ☐ Other (specify) ________

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status. See 37 CFR 1.27.

☑ A check or money order is enclosed to cover the filing fees.

☐ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number: ________

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE Amount ($): $80.00

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☑ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ________

Respectfully submitted,

SIGNATURE T.H.P. Richardson

Date April 2, 2004

REGISTRATION NO. 28805
(if appropriate)

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Docket Number: 15034

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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Docket No. 15034

SPECIFICATION FOR PROVISIONAL APPLICATION FOR PATENT ENTITLED

IMPROVED OPTICAL DETECTION DEVICE

Inventor

Don W. Arnold

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to (1) US patent application Serial No. 10/410,313, filed April 7, 2003 (Docket 14135), (2) the PCT application claiming priority from Serial No. 10/410,313 filed contemporaneously with this application by Eksigent Technologies LLC (Docket 14135-1 PCT), and (3) the copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986). The disclosure of each of the above-identified applications is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to microfluidic devices.

Background of the Invention

US patent application Serial No. 10/410,313, filed April 7, 2003 (Docket 14135), and the PCT application claiming priority from Serial No. 10/410,313 filed contemporaneously with this application by Eksigent Technologies LLC (Docket 14135-1 PCT) disclose a new optical detection device in which a liquid sample, e.g. from a liquid chromatography column, is introduced into, and removed from, the detection cell through annular passageways between the walls of the detection cell and arms, e.g. optical fibers, placed at the entrance and at the exit of the detection cell

SUMMARY OF INVENTION

The copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986) discloses novel interconnect devices which are useful for connecting microfluidic devices and conventional components, e.g. capillary tubes, optical fibers and electrical leads. These novel interconnect devices are particularly useful for positioning the optical fibers or other arms in the optical detection devices described in US patent application Serial No. 10/410,313, filed April 7, 2003 (Docket 14135), and the PCT application claiming priority from Serial No. 10/410,313 filed contemporaneously with this application by Eksigent Technologies LLC (Docket 14135-1 PCT). However, use of the novel interconnect devices results in a "dead volume" surrounding the optical fiber or other arm and extending away from the detection cell.

This invention addresses the problem of this dead volume and is also applicable to the problems arising from dead volumes in other microfluidic devices. Thus I have realized that these problems can be alleviated by placing a drain in the dead volume so that liquid entering the dead volume is removed at a rate which substantially reduces the amount of such liquid which can reenter the detection cell (or other working section) of the microfluidic device.

Thus, preferred embodiments of this invention, in conjunction with copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986) , provide an auto-aligning reversible fiber optical connector system for in-plane microfluidic detection systems, including a simple mechanism for positioning the arm and forming the annular flow region reproducibly; low dead volumes at the interconnection region; sweeping of the void volume that remains; compatibility with conventional microfabrication methodologies; and ease of use (i.e. easy connection and disconnection methods).

The detection devices disclosed in Serial No. 10/410,313 require a relatively complex assembly process, since the optical fibers and capillaries used to input light and liquid, respectively, are 'permanently' glued into the micro channels after a very careful manual alignment. By using the new connector design described in a copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986), it is to make reversible connections to the detection cell. However, when such connections are made, the resulting annular regions around the capillaries and/or optical fibers (or other arms) constitute dead volume which can result in dispersion. According to the present invention, the device is provided with one or more drains and/or by-pass channels) which provides for a continuous flushing of liquid from the 'dead-volume' region. The liquid can simply be drained to a waste reservoir, or can be passed through an auxiliary channel so that it rejoins the main liquid flow after it has left the detection cell.

The copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic

Connector (Docket 14986) describes novel interconnect devices for connecting capillaries, optical fibers or electrical leads, etc. (herein referred to as carrying elements) to microfluidic devices and the methods for their fabrication and use. There are several embodiments of this invention. As shown in Figures 1, 2a and 2b from that application (repeated here for convenience) the basic micro connector has an alignment jig chip, 12, carrying elements, 11, a sealing gasket, 13, an optional reinforcing gasket retainer, 15, microfluidic chips, 14, a holder, 16, that provides alignment during assembly and disassembly and a means, 17, for clamping the jig chip and alignment chip.

The alignment jig, 12, and microfluidic chip, 14, are both microfabricated. An important feature of these two components is that they are designed to have features that match at the edges where the interconnection is to be made. Particularly, the channel openings, 18, in the edge of the microfluidic chips are designed so that when the edges of the chips are aligned, the openings are aligned. In one embodiment, the dimensions (height, width and length) are designed to be the same to insure accurate alignment with quite simple assembly procedures. In other embodiments, the use of edges is replaced with other alignment mechanisms that do not require extremely precise geometric dimensions.

Further details about the connector can be obtained from copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986).

Shown in Figures 3a-c is an apparatus that can perform photometric measurements on a flowing liquid sample with reduced dispersion. The device comprises a body, 27, containing conduits that will accommodate optical fibers and capillaries, light carrying optical fibers, 21 (entrance) and 25 (exit), fluid carrying capillaries, 23 (entrance) and 26 (exit), an annular flow region, 22, and a detection region, 24. Reduced dispersion is accomplished by incorporating an annular flowpath, 22, around optical fibers, 21 and 25, at either end of a detection cell. This design tends to counteract the dispersion inherent in the normal Poiseuille (parabolic velocity profile) flow through the detection cell. The annular flowpath, 22, also reduces dispersion by minimizing unswept volumes. This disclosure also includes a method for fabricating this

flow cell design within a silica "chip" structure. This structure is comprised of two silica wafers into which have been etched semicircular troughs. These wafers, when bonded, form conduits having a cylindrical cross-section through what is essentially a planar silica piece.

Shown in Figure 4 is a combination of the disclosures in the applications incorporated by reference. This combination is a useful, novel and inventive device on its own. This embodiment addresses the issues of reversible connections for the optical fibers. In situations where the flow cell becomes clogged by debris, this embodiment allows the disassembly and flushing of the detection path, followed by reassembly to allow reuse. For the embodiment taught in Serial number 10/410,313, if the detection cell becomes clogged, the device must either be replaced or undergo a very laborious regeneration process in which the existing fibers and capillaries are destroyed and replaced with new elements. As shown, the carrying element, alignment jig and gasket are formed into an assembly, 29, and inserted into the flow cell. The gasket, 13, can be of any of the designs and materials described in the copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986). In applications requiring low-pressure (less than about 500 psi) detection, the gasket can be used alone. For high pressures, a gasket retainer may be desirable. Any means of alignment described in the copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986) can be used to simply the assembly. The embodiment still suffers from the presence of a dead volume in the region around the fiber optic between the edge of the flow cell and the inlet capillary, 23.

In order to achieve reproducible performance from the detection cell during absorbance measurements, the length of the detection region, 24, is preferably the same from cell to cell. This requires that the length of optical fiber, L, inserted into the chip must be very reproducible (assumes that the dimension of the chip is also reproducible, but means for accomplishing the necessary control for this dimension are well known in the art by lithographic definition of dicing lines and use of precision dicing

equipment). Figures 5a and 5b illustrate a method for reproducibly defining the length of capillary that will be inserted into the flow cell. The method requires the use of a fiber placement tool, 60, with a channel of defined length, such that when the alignment jig, 12, is positioned with the gasket, 13, in the same manner as will be used with the flow cell, the fiber will insert to a length that closely approximates the length, L, required for the flow cell. Once the fiber is inserted to its end position, it is fixed in place in the alignment jig, 12, by placing adhesives or other acceptable materials in the annular region, 31, between the optical fiber, 21, and the channel wall, prior to removal of the assembly, 29, from the fiber placement tool, 60.

Figure 6 shows the further improved detection cell. In addition to all the features in Figure 4, the device includes a bypass channel where the inlet is located between the fluid inlet and the edge of the chip by a distance, L2, and the outlet is between the annular region around the exit fiber, 25, and the inlet, 71, to the exit capillary, 26. This bypass channel is of a smaller dimension than the detection region. The actual size is selected so that a small, but finite, percentage of the fluid flow from the inlet capillary, 23, to the exit capillary, 26 travels through the bypass channel. The percentage should be less than 5%, but is much more preferably lower than 1% of the total liquid flow rate through the flow cell. This small amount of flow serves to sweep the dead volume that results from using the reversible connector in this flow cell embodiment. Collection of the liquid after the detection region insures that analytes that may have diffused into the dead volume (in the connector annular region) will bypass the detection region and thus will not reduce the performance of the flow cell by introducing dispersion, peak distortion or carryover.

Typically, the detection region has a cylindrical shape with a diameter of order 100 micrometers. However, most of the flow-rate-determining pressure drop occurs across the annular flow region, which is approximately 1-2 microns thick around the optical fiber over a length of 1mm. Typical pressure drops across the flow cell are on the order of 50 psi at flow rtes of 10 uL/min. One would desire a bypass channel that gives on the order of 100 nL/min at the same pressure. Such channel would have a diameter

on the order of 1-2 micrometers over the 4 mm length. The channel need not be cylindrical. If not, adjustments to the dimensions should be made to account for the hydraulic diameter using standard engineering formulas for pressure-driven flow through conduits of the appropriate shape.

The bypass channel, as drawn in Figure 6, breaks the symmetry of the flow cell. In practice, this places a direction of flow on the cell. However, symmetry can be restored by connecting the by pass channel exit to the annular region around the collection fiber, 25. However, if the sample from the exit of the detection cell is to be passed into a second analyzer of any kind (e.g. a mass spectrometer), peak echos (or foreshadowing, or dispersion) can occur due to some small part of a big peak entering the cell traveling along the by pass channel and rejoining the main flow near the exit. Thus, this flow cell design is less well suited for such applications in which it is one of the earlier detectors in a tandem detection system. However, this disadvantage can be remedied by providing a separate exit for the liquid that travels through the bypass channel or by placing the exit of the bypass channel in the annular region of the collection fiber.

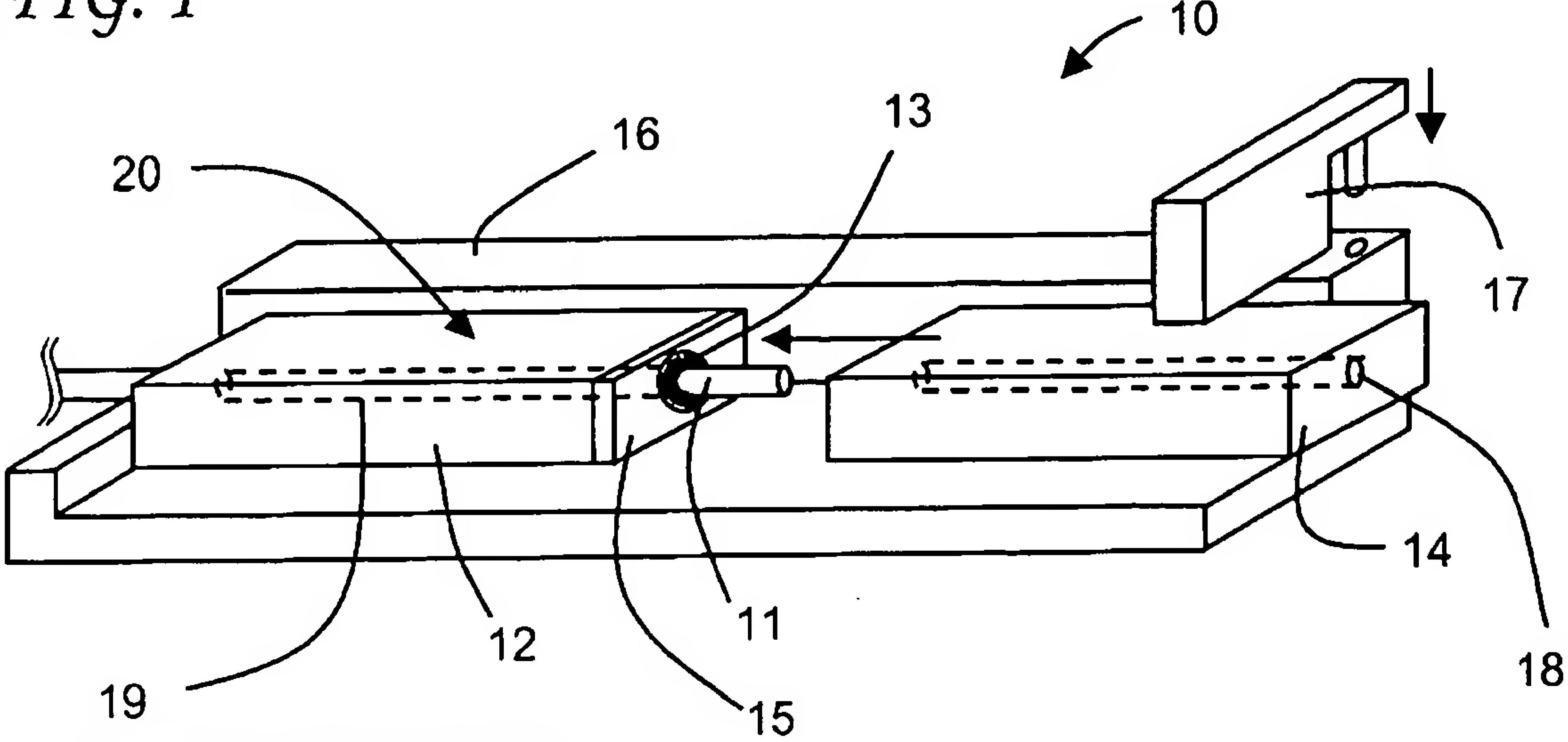
Figure 7 illustrates another embodiment of the invention in which additional alignment elements, 80, are added to the alignment jig assembly, 29, positioned in the alignment jig, 12, in the same manner at the fiber optic. As pointed out in the copending, commonly assigned United States application filed contemporaneously with this application by Don Arnold et al. and entitled Microfluidic Connector (Docket 14986), for fiber optic connections, these additional alignment elements, 80, serve as fine alignment elements and protect the face of the optical fiber during installation.

Figure 8 illustrates another embodiment of the invention in which the liquid carrying capillaries, 23 and 26, are included in the alignment jig assembly. In this way, both the fluidic and optical connections are made or broken simultaneously. It is to be pointed out that although this disclosure has focused on the nature of the fiber optical connection to the flow cell, the liquid capillary connections can be connected through the same edge connections as described for the fiber optical connections in this disclosure.

What is claimed is:

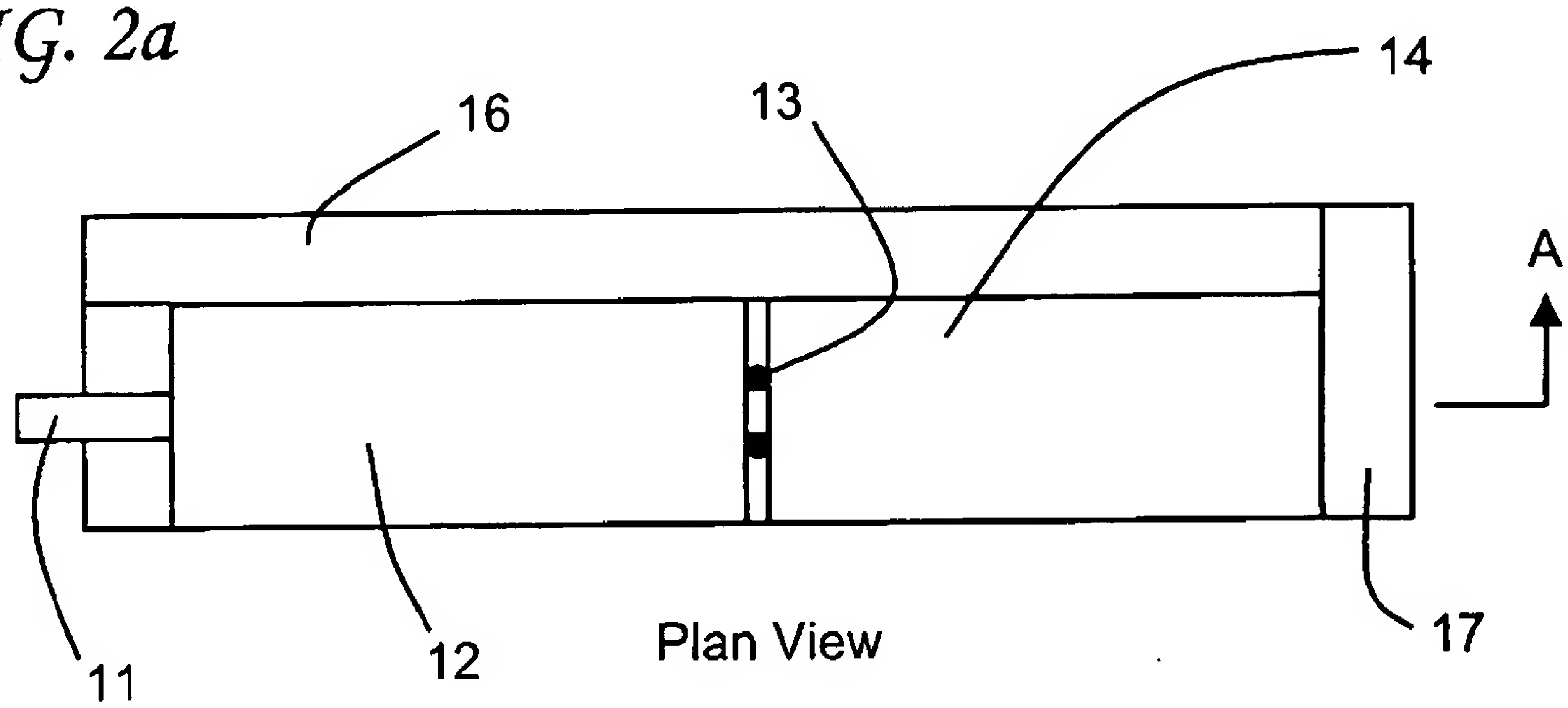
A microfluidic device substantially as illustrated in Figure 6.

FIG. 1



CONNECTOR (EK-034)

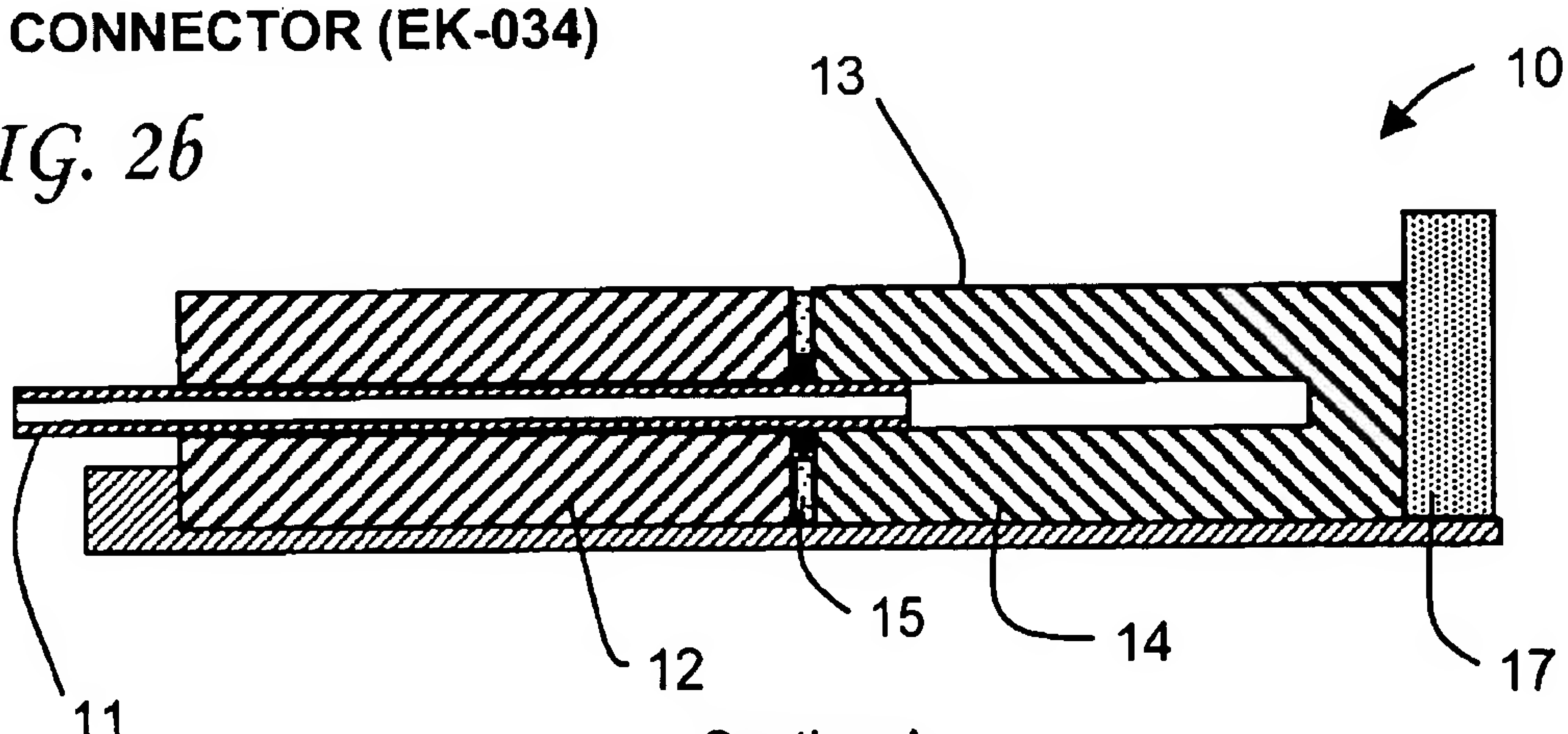
FIG. 2a



Plan View

CONNECTOR (EK-034)

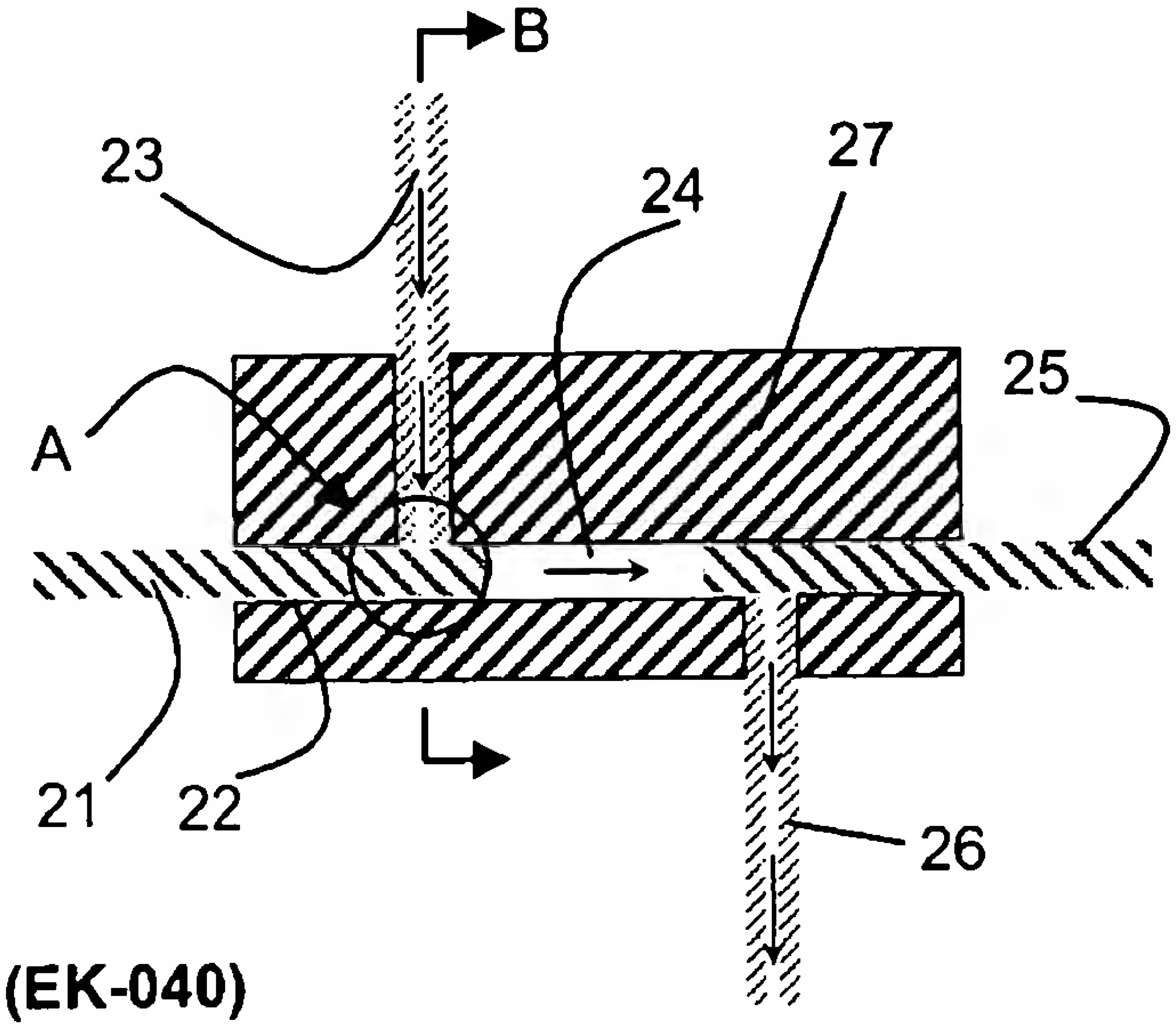
FIG. 2b



Section A

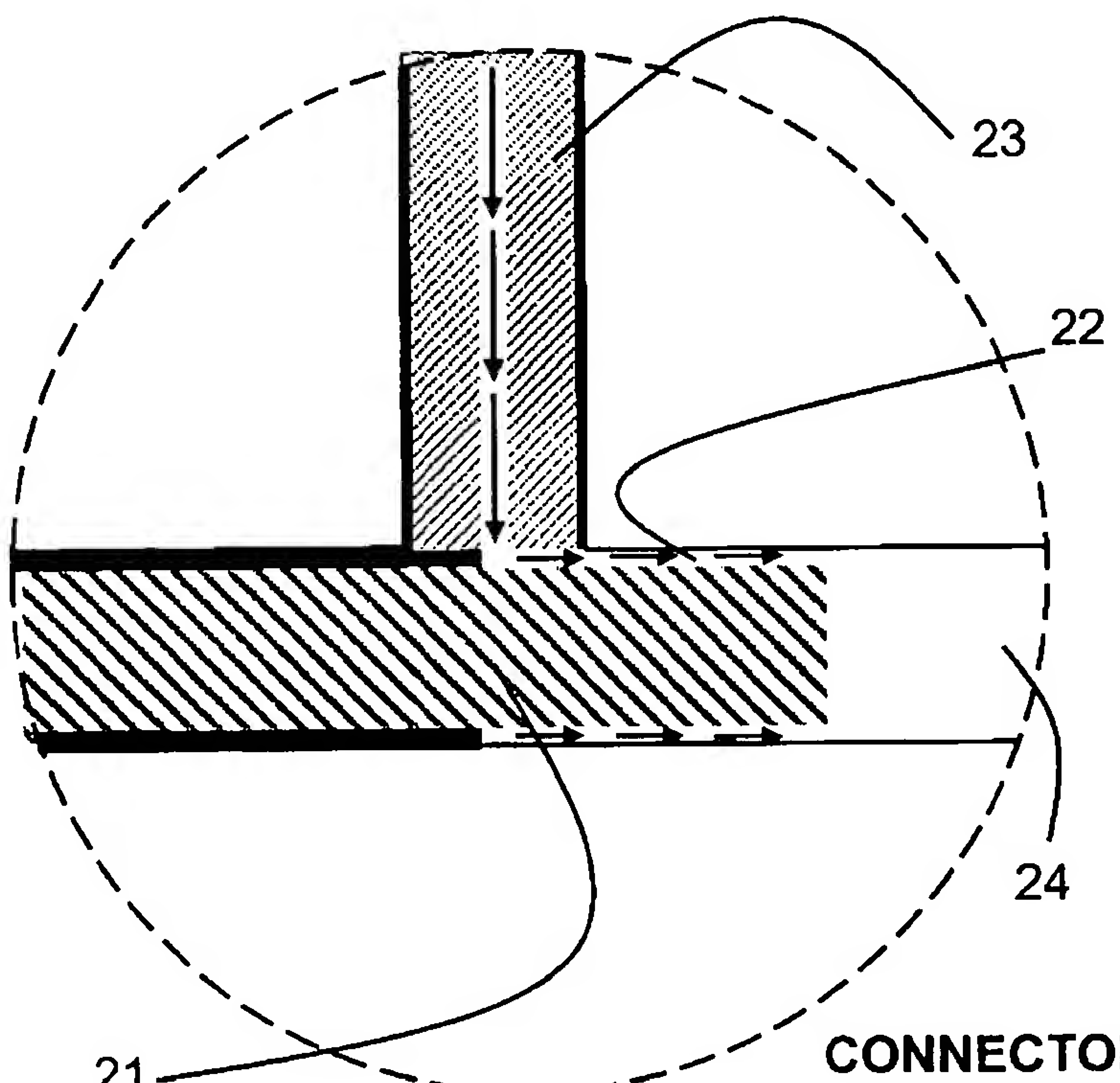
CONNECTOR (EK-034)

FIG. 3a



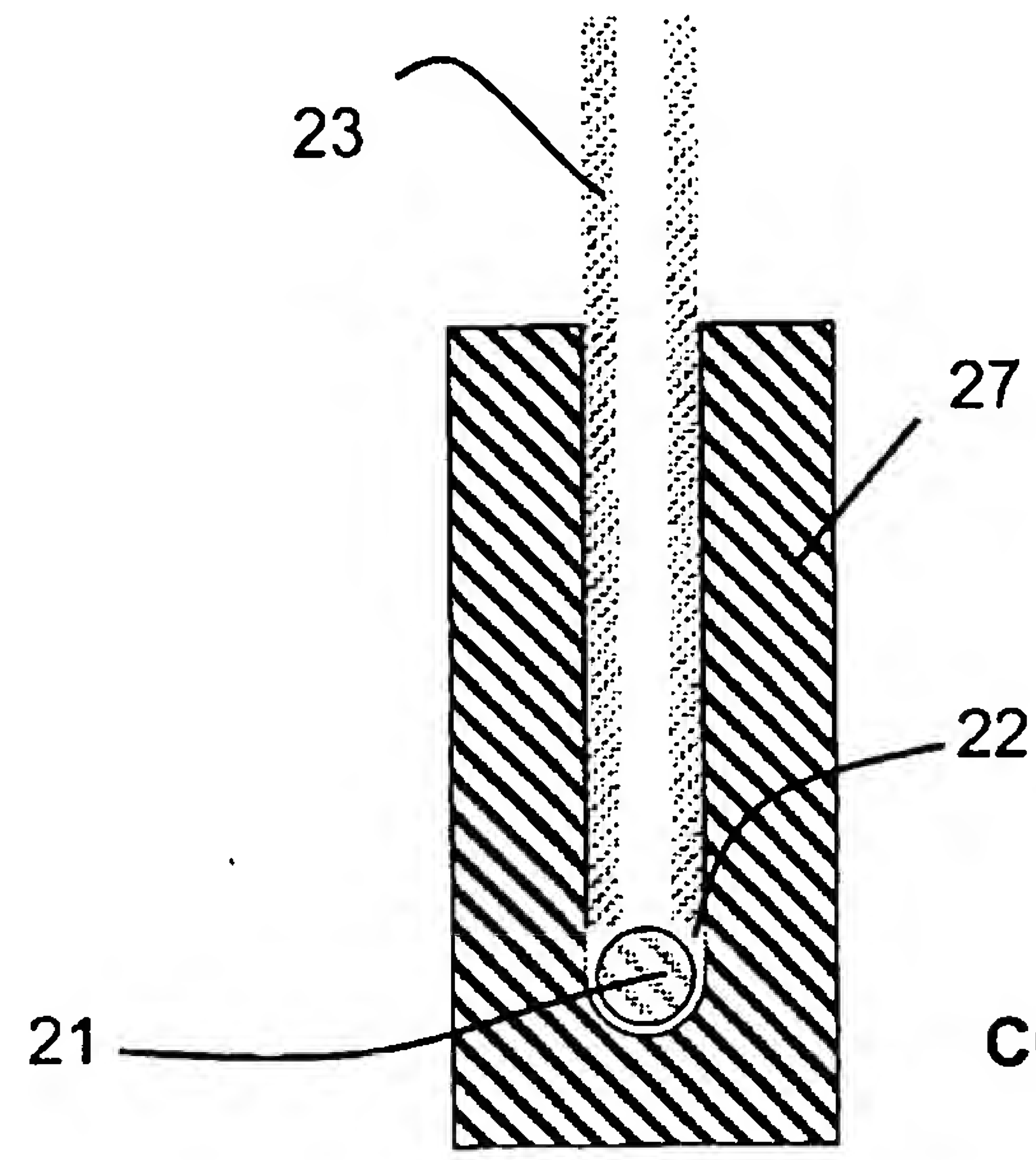
CONNECTOR (EK-040)

FIG. 3b



CONNECTOR (EK-040)
Inset A

FIG. 3c



CONNECTOR (EK-040)
Section B

FIG. 4

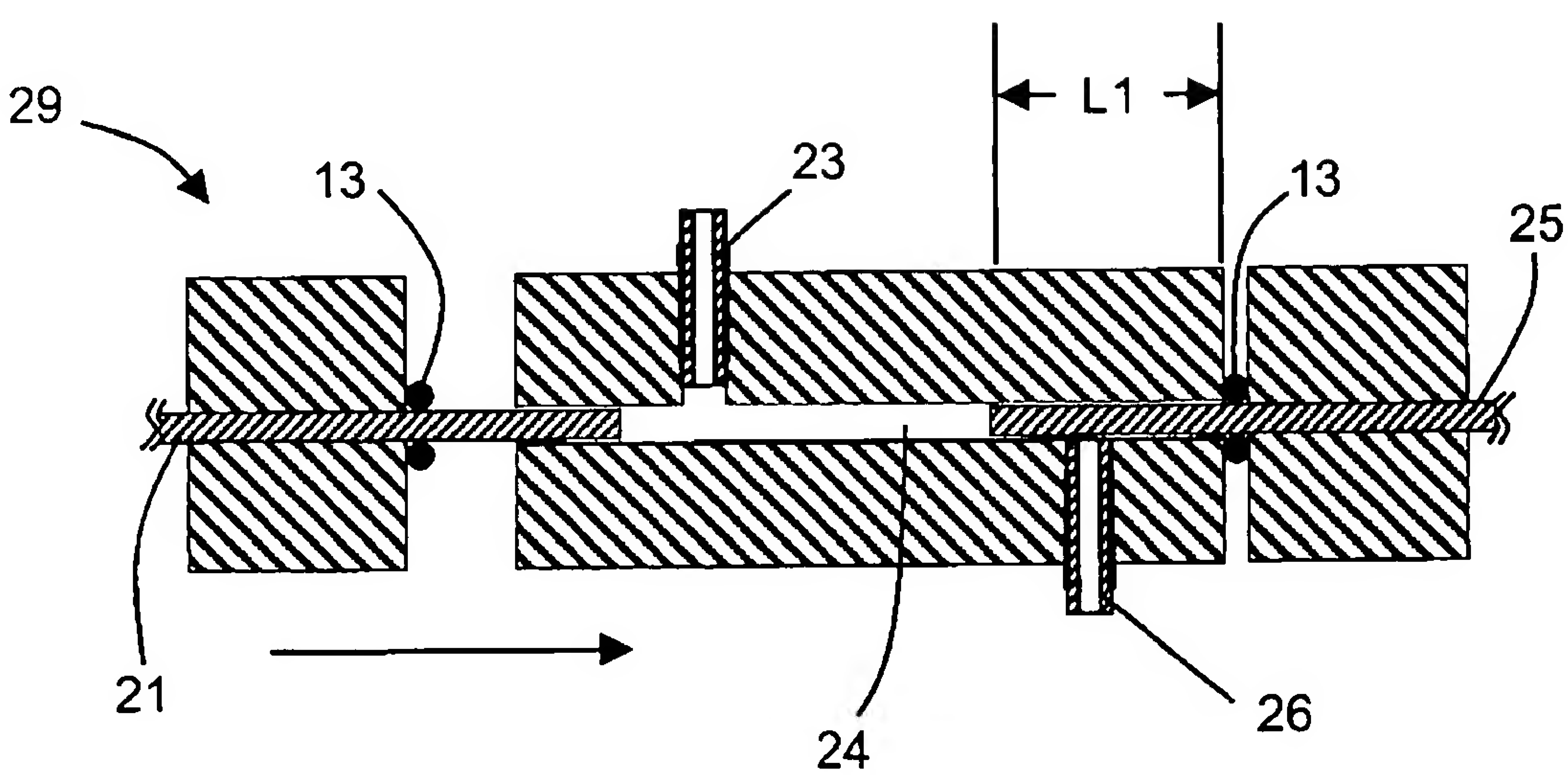


FIG. 5a

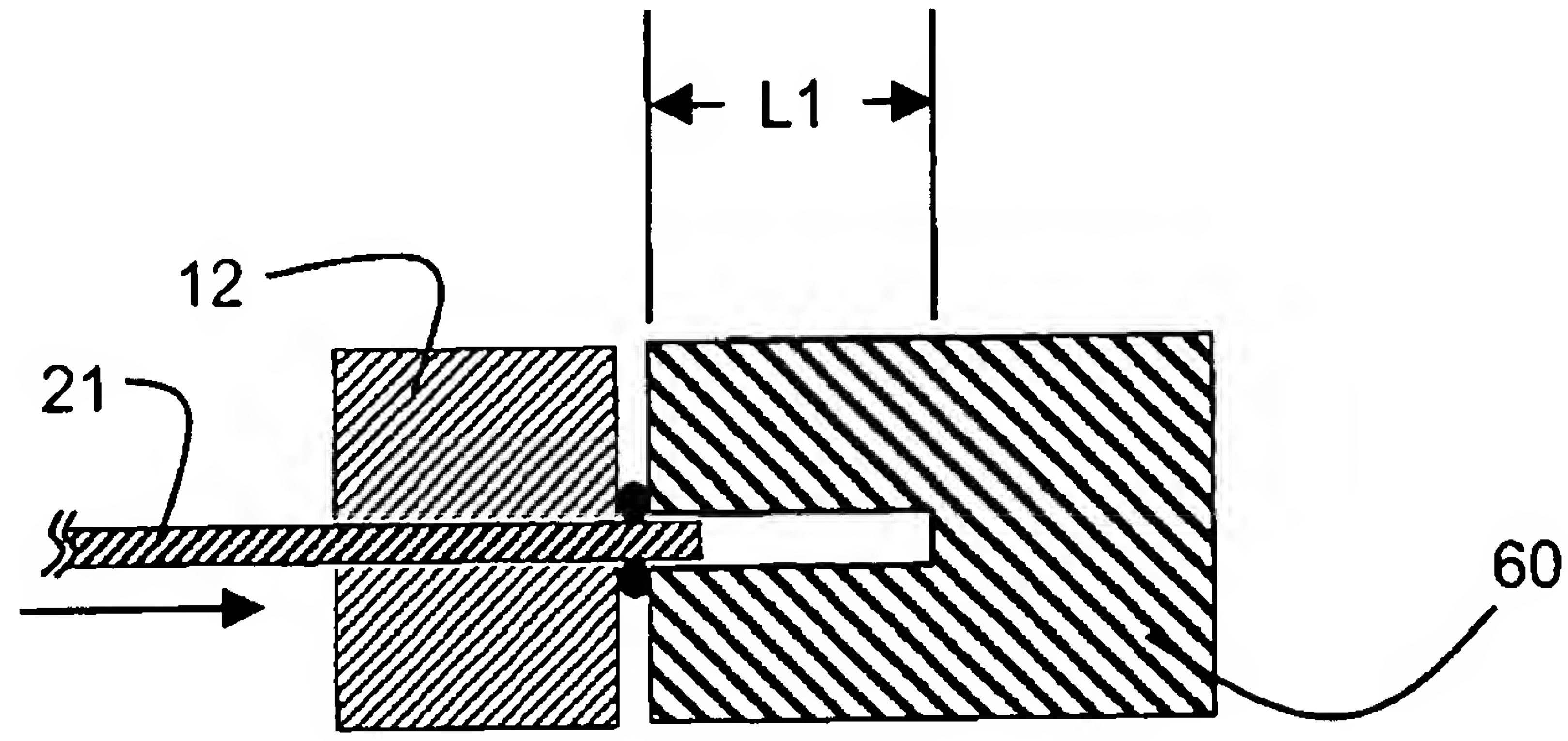


FIG. 5b

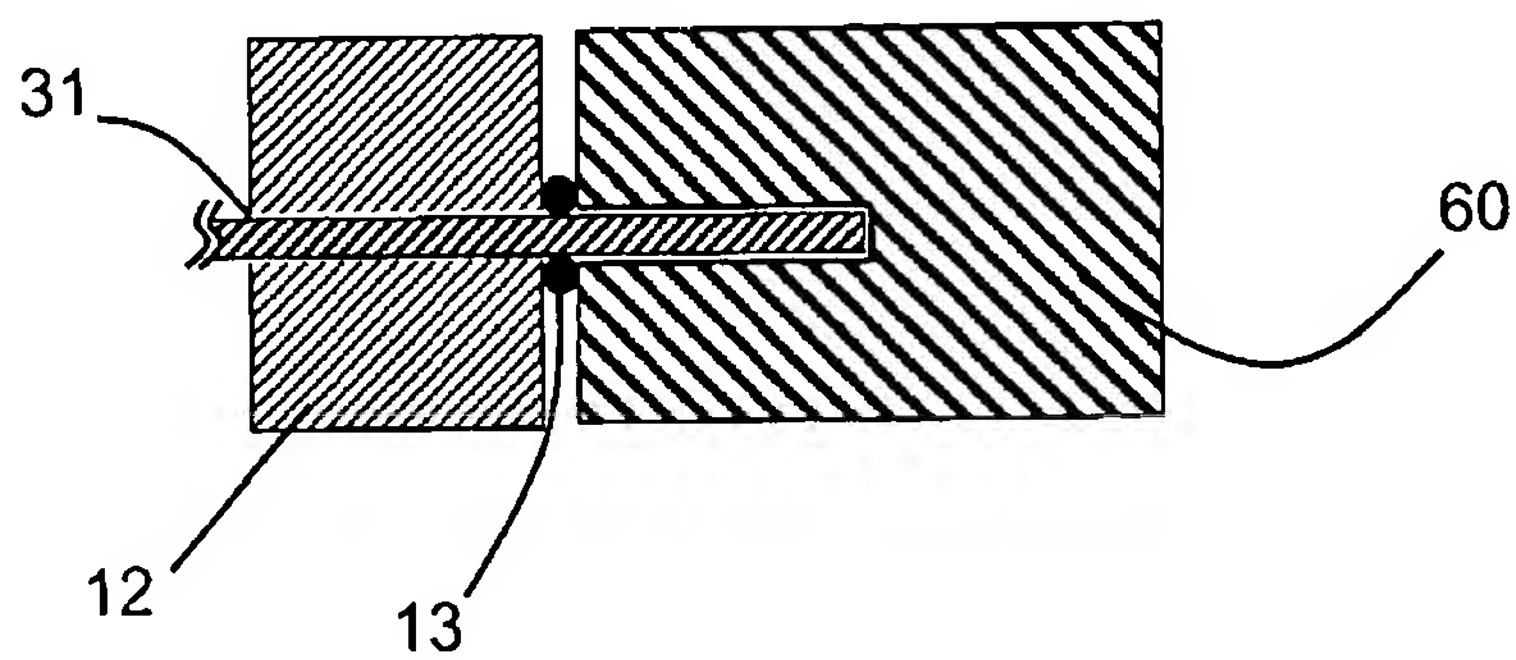


FIG. 6

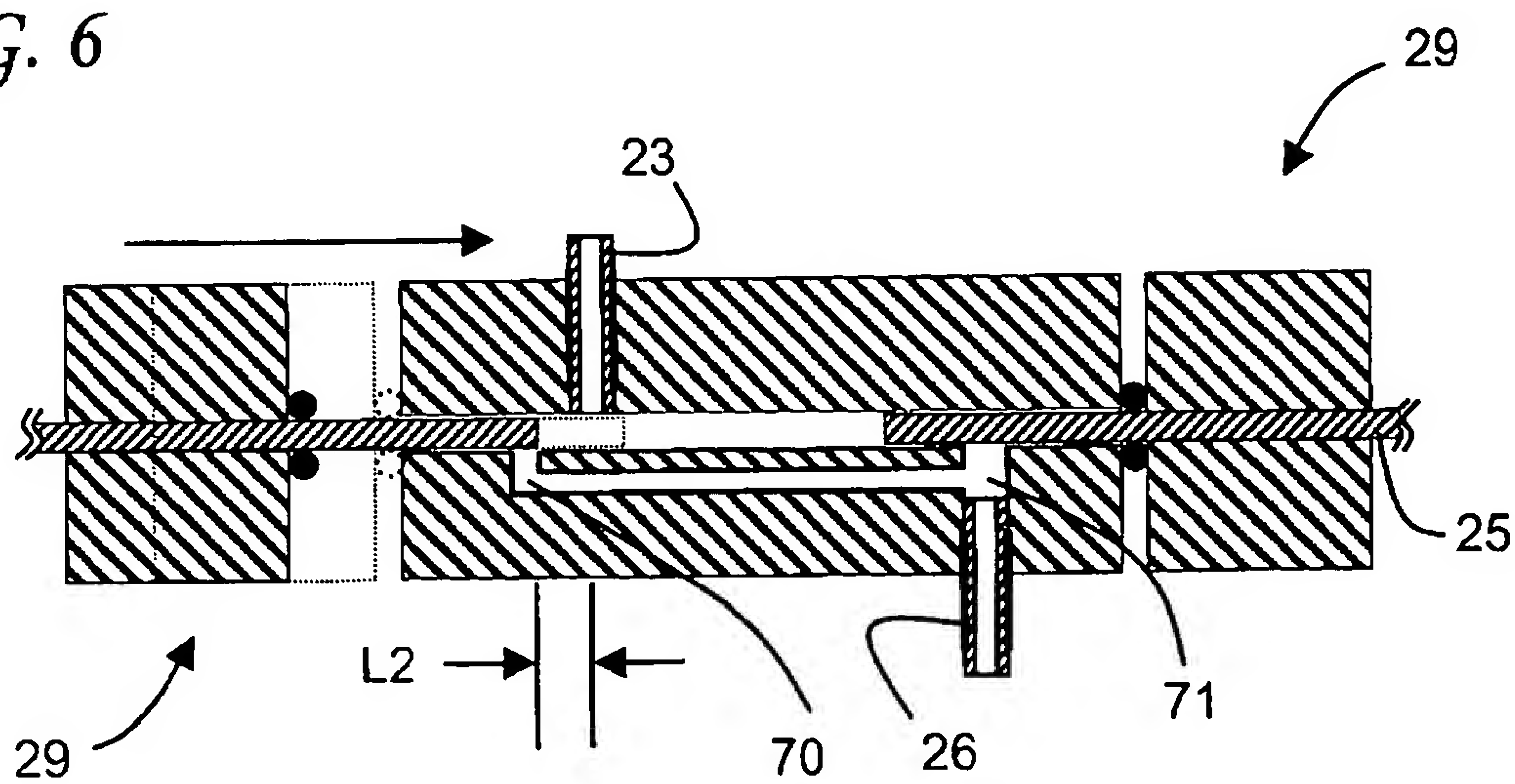


FIG. 7

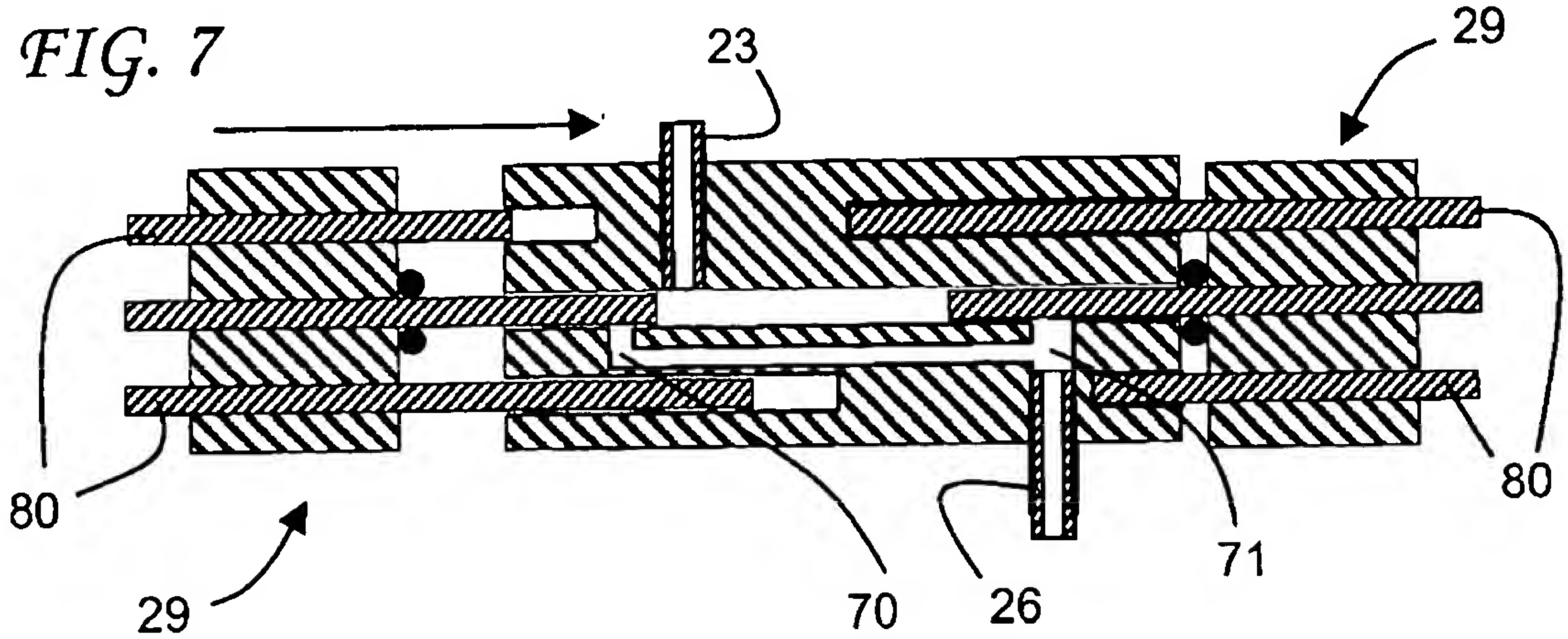


FIG. 8